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Candidate number

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Surname

StemUp Model Solution

Forename(s)

Candidate signature

I declare this is my own work.

A-level BIOLOGY

Paper 2

Thursday 11 June 2020

Morning

Time allowed: 2 hours

Materials

For this paper you must have:

- a ruler with millimetre measurements
- a scientific calculator.

Instructions

- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- Show all your working.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information

- The marks for the questions are shown in brackets.
- The maximum mark for this paper is 91.

For Examiner's Use	
Question	Mark
1	
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TOTAL	



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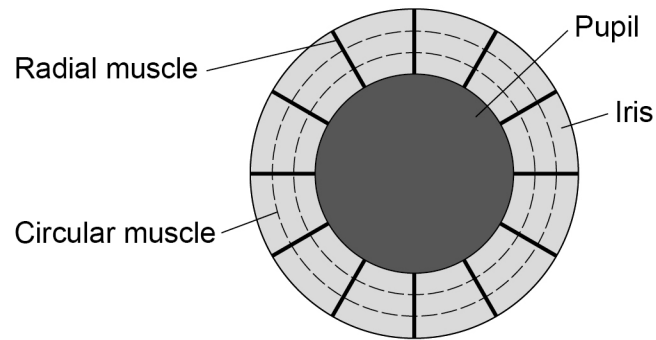
Answer **all** questions in the spaces provided.

0 1

The iris in the human eye is a muscular structure. The iris changes the size of the pupil.

Figure 1 shows the muscles in the iris.

Figure 1



0 1 . 1

Suggest and explain how the interaction between the muscles labelled in **Figure 1** could cause the pupil to constrict (narrow).

[2 marks]

The circular muscle contracts and the radial muscle relaxes.

This pulls the iris inwards, so the diameter of the pupil gets smaller and the pupil constricts.



0 1 . 2

The fovea of the eye of an eagle has a high density of cones. An eagle focuses the image of its prey onto the fovea.

Explain how the fovea enables an eagle to see its prey in detail.

Do **not** refer to colour vision in your answer.

[3 marks]

The fovea gives high visual acuity.

This is because each cone is connected to a single (bipolar) neurone, so there is no retinal convergence.

So the cones send separate sets of impulses to the brain (via the optic nerve), allowing the eagle to distinguish between two points close together and see its prey in fine detail.

0 1 . 3

The retina of the human eye has an area of approximately $1.094 \times 10^3 \text{ mm}^2$

The circular fovea in a human eye has a diameter of $3 \times 10^3 \text{ }\mu\text{m}$

Calculate the area of the fovea as a percentage of the area of the retina.

The area of a circle is πr^2 . Use $\pi = 3.14$ in your calculation.

Show your working.

[2 marks]

Diameter = $3 \times 10^3 \text{ }\mu\text{m} = 3 \text{ mm}$, so $r = 1.5 \text{ mm}$

Area of fovea = $3.14 \times 1.5^2 = 7.065 \text{ mm}^2$

Percentage = $(7.065 \div 1094) \times 100 = 0.646\%$

Answer 0.65 %

Question 1 continues on the next page

Turn over ►



0 1 . 4

The retina of an owl has a high density of rod cells.

Explain how this enables an owl to hunt its prey at night.

Do **not** refer to rhodopsin in your answer.

[3 marks]

Rods give high visual sensitivity, so the owl can see in dim light at night.

This is because several rods are connected to a single (bipolar) neurone (retinal convergence).

So even in low light intensity, the small generator potentials from many rods combine (spatial summation), releasing enough neurotransmitter to reach the threshold in the bipolar neurone, so an action potential is produced and impulses go to the brain.



0 2

Testosterone is a steroid hormone that belongs to a group of male sex hormones called androgens.

0 2 . 1

Steroid hormones are hydrophobic.

Explain why steroid hormones can rapidly enter a cell by passing through its cell-surface membrane.

[2 marks]

Steroid hormones are lipid soluble.

So they can diffuse directly through the phospholipid bilayer of the cell-surface membrane, without needing to pass through proteins.

0 2 . 2

In the cytoplasm, testosterone binds to a specific androgen receptor (AR). An AR is a protein.

Suggest and explain why testosterone binds to a specific AR.

[2 marks]

The androgen receptor is a protein with a specific tertiary structure, giving its binding site a specific shape.

Only testosterone has a shape that is complementary to this binding site, so only testosterone can bind to the AR.

Question 2 continues on the next page

Turn over ►



0 2 3

The binding of testosterone to an AR changes the shape of the AR. This AR molecule now enters the nucleus and stimulates gene expression.

Suggest how the AR could stimulate gene expression.

[2 marks]

The AR acts as a transcription factor.

It binds to the promoter region of a target gene's DNA, which

stimulates RNA polymerase to bind and start transcription of the gene.

The gene that codes for the AR has a variable number of CAG repeats. Some studies have shown an association between the number of CAG repeats and the risk of developing prostate cancer.

Table 1 shows the results of a statistical test from one study.

Table 1

Number of CAG repeats in the AR gene	Probability (P) value
≤ 16	0.02
≤ 17	0.30
≤ 18	0.07
≤ 19	0.09
≥ 20	0.06

0 2 4

What can you conclude from the data in **Table 1**?

[3 marks]

With 16 or fewer CAG repeats, the association with prostate cancer is

significant, because $P = 0.02$, so there is less than a 0.05 (5%)

probability that it is due to chance. So we reject the null hypothesis.

With 17 or more repeats, the association is not significant, because all

the P values are greater than 0.05, e.g. $P = 0.30$ means a 30%

probability that the result is due to chance. So we accept the null

hypothesis.

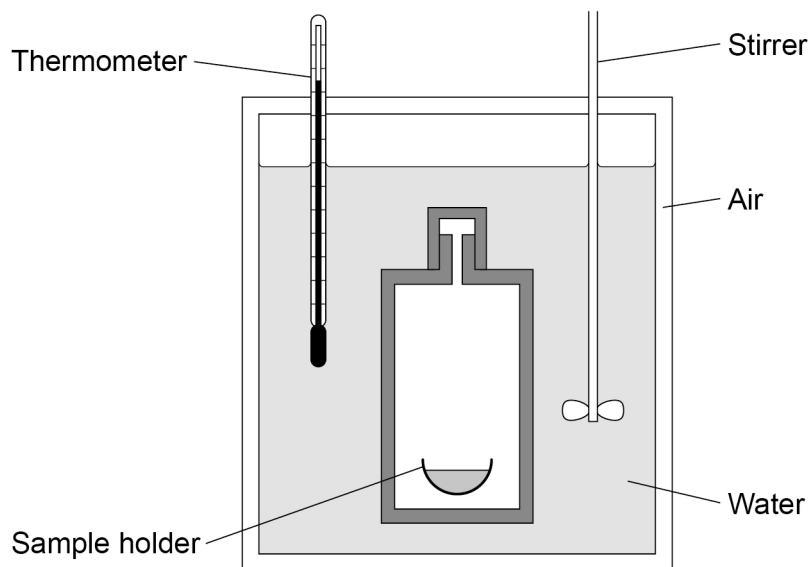
So prostate cancer is more likely with 16 or fewer repeats.



0 3

Figure 2 shows one type of calorimeter.

Figure 2



A calorimeter can be used to determine the chemical energy store of biomass. A known mass of biomass is fully combusted in a calorimeter. The heat energy released from this combustion increases the temperature of the water in the calorimeter. The increase in the temperature of a known volume of water is recorded.

0 3

1

Other than the thermometer, explain how **two** features of the calorimeter shown in Figure 2 would enable a valid measurement of the total heat energy released.

[2 marks]

1 *The stirrer distributes the heat energy evenly through the water, so the temperature is the same throughout.*

2 *The air (space) acts as insulation, reducing heat loss to the surroundings by conduction and convection.*

Question 3 continues on the next page

Turn over ►



0 3 . 2

A 2 g sample of biomass was fully combusted in a calorimeter.

The volume of water in the calorimeter was 100 cm³

The increase in temperature recorded was 15.7 °C

4.18 J of energy are needed to increase the temperature of 1 cm³ of water by 1 °C

Use this information to calculate the heat energy released in kJ per g of biomass.

Show your working.

[2 marks]

$$\text{Energy} = 100 \times 15.7 \times 4.18 = 6562.6 \text{ J}$$

$$\text{Per gram} = 6562.6 \div 2 = 3281.3 \text{ J g}^{-1}$$

$$= 3.28 \text{ kJ g}^{-1}$$

Answer 3.28 kJg⁻¹

Plants and algae produce fuels called biofuels. Scientists have used *Chlorella* to produce biofuel. *Chlorella* is a genus of single-celled photosynthetic alga. *Chlorella* can be grown in open ponds and fermenters.

0 3 . 3

In natural ecosystems, most of the light falling on producers is **not** used in photosynthesis.

Suggest **two** reasons why.

[2 marks]

1 Some of the light is reflected off the leaves (or is the wrong wavelength to be absorbed by chlorophyll).

2 Some light misses the chloroplasts / chlorophyll, or CO₂ concentration or temperature is the limiting factor.



0 3 . 4

The light absorbed by chlorophyll is used in the light-dependent reaction.

Name the **two** products of the light-dependent reaction that are required for the light-independent reaction.

[2 marks]

1 ATP2 Reduced NADP

0 3 . 5

Chlorella cells can divide rapidly. A culture of 2000 *Chlorella* cells was set up in a fermenter. The cells divided every 90 minutes.

You can assume that there were no limiting factors and that no cells died during the 24 hours.

Calculate the number of cells in the culture after 24 hours.

Give your answer in standard form.

Show your working.

[2 marks]

$$\text{Number of divisions} = (24 \times 60) \div 90 = 16$$

$$\text{Cells} = 2000 \times 2^{16} = 2000 \times 65\,536$$

$$= 131\,072\,000$$

Answer 1.31×10^8

10

Turn over for the next question

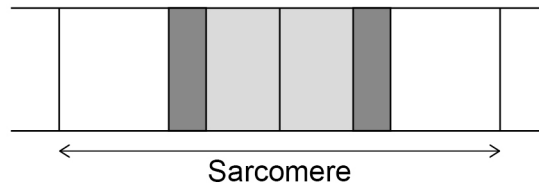
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0 4

Figure 3 shows the banding pattern of a single sarcomere.

Figure 3



0 4 . 1

Explain the banding pattern shown in **Figure 3**.

[3 marks]

The light bands (I bands) at each end contain only thin actin filaments.

The lighter region in the centre (H zone) contains only thick myosin filaments.

The darkest regions are where the actin and myosin filaments overlap.



Creatinine is produced in muscle tissues. Creatinine diffuses into the blood. The kidneys then excrete creatinine.

A calibration curve can be used to determine the concentration of creatinine in urine. One method of producing a calibration curve needs:

- creatinine solution of known concentration
- distilled water
- creatinine-detecting solution
- a colorimeter.

Creatinine-detecting solution reacts with creatinine to produce an orange colour.

0 4 . 2

Use the information provided to describe how you could produce a calibration curve for creatinine.

Do **not** include details on the use of glassware in your answer.

[4 marks]

Use the creatinine solution of known concentration and distilled water to make a dilution series, e.g. a range of five concentrations from 0 up to the stock concentration.

Add the same known volume of creatinine-detecting solution to the same known volume of each diluted creatinine solution, and leave for the same time for the orange colour to develop.

Put each solution in a colorimeter and record its absorbance (using a suitable filter and zeroing the colorimeter with distilled water).

Plot a graph of creatinine concentration against absorbance and draw a calibration curve.

Turn over ►



0 4 . 3

Describe how you would determine the concentration of creatinine in a urine sample using your calibration curve.

[2 marks]

Add the same volume of creatinine-detecting solution to the same volume of the urine sample as used for the calibration curve, and measure its absorbance in the colorimeter.

Then read off the creatinine concentration on the calibration curve that matches this absorbance value.

9

0 5

Describe the sequence of events involved in transmission across a cholinergic synapse.

Do **not** include details on the breakdown of acetylcholine in your answer.

[5 marks]

An action potential arrives at the synaptic knob, causing depolarisation of the presynaptic membrane.

This causes voltage-gated calcium ion channels to open, so Ca^{2+} ions diffuse into the synaptic knob.

The calcium ions cause synaptic vesicles to move to and fuse with the presynaptic membrane, releasing acetylcholine into the synaptic cleft by exocytosis.

Acetylcholine diffuses across the synaptic cleft and binds to specific receptors on the postsynaptic membrane.

This causes sodium ion channels to open, so Na^+ ions diffuse into the postsynaptic neurone, causing depolarisation. If the threshold is reached, an action potential is generated.

5

Turn over ►



06.1

Mutation is one cause of genetic variation in organisms.

Give **two** other causes of genetic variation.

[2 marks]

1 *Crossing over between homologous chromosomes in meiosis.*

2 *Independent segregation of homologous chromosomes, and random fertilisation of gametes.*

In a species of flowering plant, the **T** allele for tallness is dominant to the **t** allele for dwarfness. In the same species, two alleles **C^R** (red) and **C^W** (white) code for the colour of flowers. When homozygous red-flowered plants were crossed with homozygous white-flowered plants, all the offspring had pink flowers.

06.2

Name the relationship between the two alleles that code for flower colour.

[1 mark]

Codominance



0 6 . 3

A dwarf, pink-flowered plant was crossed with a heterozygous tall, white-flowered plant.

Complete the genetic diagram to show all the possible genotypes and the ratio of phenotypes expected in the offspring of this cross.

[3 marks]

Phenotypes of parents: Dwarf, pink-flowered × Tall, white-flowered

Genotypes of parents: $ttC^R C^W$ $TtC^W C^W$

Gametes: tC^R tC^W TC^W tC^W

	TC^W	tC^W
tC^R	$TtC^R C^W$	$ttC^R C^W$
tC^W	$TtC^W C^W$	$ttC^W C^W$

Genotypes of offspring: $TtC^R C^W$ $TtC^W C^W$ $ttC^R C^W$ $ttC^W C^W$

Phenotypes of offspring: tall pink : tall white : dwarf pink :
dwarf white

Ratio of phenotypes: 1 : 1 : 1 : 1

0 6 . 4

A population of this species of plant contained 9% of red-flowered plants.

Use the Hardy–Weinberg equation to calculate the percentage of pink-flowered plants in this population.

Show your working.

[2 marks]

$$\text{Red} = C^R C^R = p^2 = 0.09, \text{ so } p = 0.3$$

$$q = 1 - 0.3 = 0.7$$

$$\text{Pink} = 2pq = 2 \times 0.3 \times 0.7 = 0.42$$

Answer 42 %

8

Turn over ►



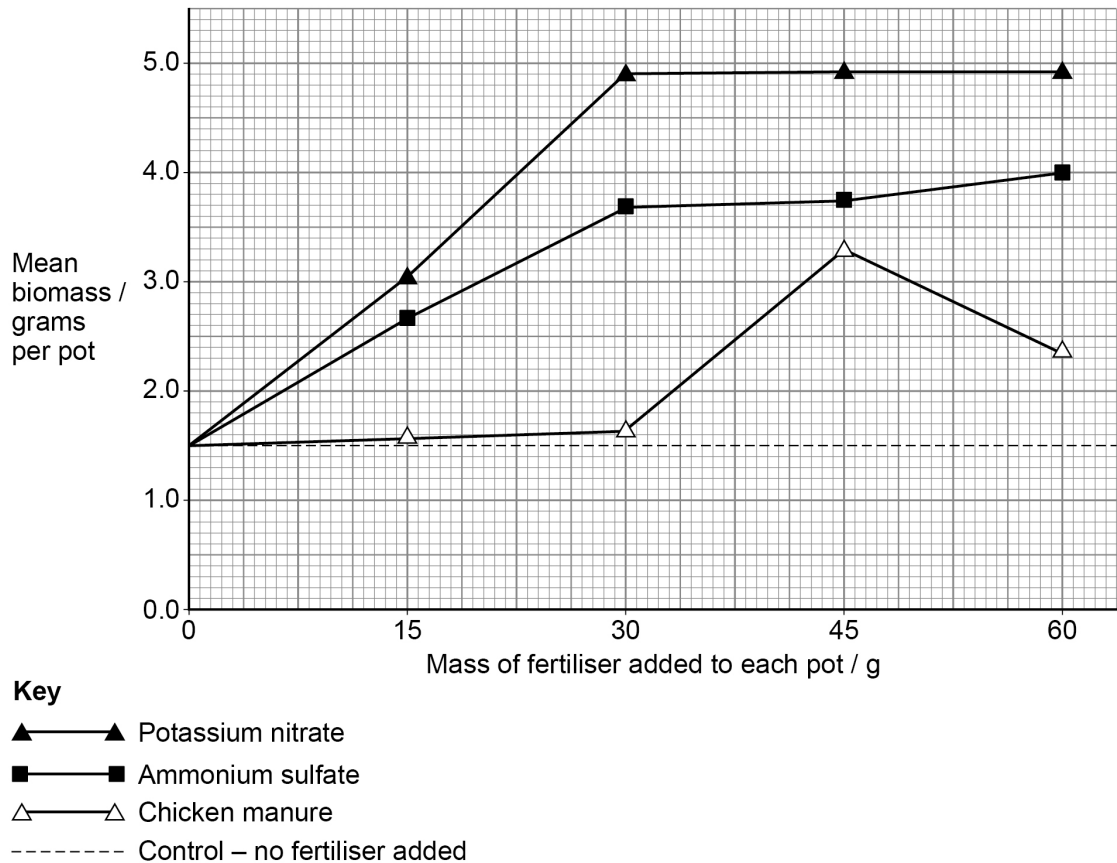
0 7

A scientist investigated the effects of different fertilisers on the growth of spinach plants. The scientist:

- set up a large sample of identical pots of soil
- added different masses of different fertilisers to selected pots
- did not add fertiliser to the control pots
- planted the same number of young spinach plants in each pot
- after 20 days, determined the biomass of spinach plants in each pot.

The results the scientist obtained after 20 days are shown in **Figure 4**.

Figure 4



0 7 . 1

Calculate how many times greater the mean growth rate per day was using 37.5 g potassium nitrate than using 37.5 g ammonium sulfate.

Assume the mean biomass of the spinach plants at the start of the investigation was 0.5 g per pot.

[1 mark]

Potassium nitrate: $(4.9 - 0.5) \div 20 = 0.22 \text{ g per day}$

Ammonium sulfate: $(3.7 - 0.5) \div 20 = 0.16 \text{ g per day}$

$0.22 \div 0.16 = 1.375$

Answer 1.375



0 7 . 2

Using all the information, evaluate the effect on plant growth of adding the different fertilisers to the soil.

[5 marks]

Potassium nitrate is the most effective fertiliser and chicken manure is the least effective, although all the fertilisers give more growth than the control at every mass.

With potassium nitrate there is no further increase in biomass above 30 g, and ammonium sulfate shows only a small, gradual increase after 30 g. The effectiveness of chicken manure decreases after 45 g (it is lower at 60 g).

The fertilisers probably provide a source of nitrogen (nitrate / ammonium ions) which the plants use to make proteins (and nucleic acids) for growth.

However, no statistical test was done and there are no SDs or error bars, so we cannot tell if the differences are significant. Also, the results are only for spinach, so may not apply to other plants.

0 7 . 3

The scientist determined the dry mass of the spinach plants. First, he heated each sample at 80 °C for 2 hours.

Suggest what the scientist should do to ensure that he has removed all the water from the sample.

[2 marks]

Weigh the sample, then heat it again (at 80 °C) and reweigh it, repeating this.

Keep heating and weighing until the mass stays constant, which shows all the water has been removed.



0 8

Alport syndrome (AS) is an inherited disorder that affects kidney glomeruli of both men and women. Affected individuals have proteinuria (high quantities of protein in their urine).

0 8 . 1

Suggest how AS could cause proteinuria.

[2 marks]

AS could damage the basement membrane of the glomerulus (e.g. faulty collagen), or make more protein channels / gaps in it.

So large proteins can pass out of the blood into the glomerular filtrate in the renal (Bowman's) capsule and are not reabsorbed, so they end up in the urine.

0 8 . 2

AS results from a sex-linked mutation.

In a male with AS, where would the sex-linked mutation be located?

Tick (✓) **one** box.

[1 mark]

The homologous section of a Y chromosome

☐

The homologous section of an X chromosome

☐

The non-homologous section of a Y chromosome

☐

The non-homologous section of an X chromosome

☒


Scientists investigated the use of transplanted stem cells to treat AS in mice.

The scientists set up four experimental groups.

Group **A** – 40 wild type* mice

Group **B** – 40 AS mice

Group **C** – 40 AS mice that received stem cells from AS mice

Group **D** – 40 AS mice that received stem cells from wild type mice

*Wild type mice are mice **not** affected by AS.

After 20 weeks, the scientists measured the quantity of protein in the urine using a scale from 0 (lowest quantity) to +++++ (highest quantity).

The results the scientists obtained are shown in **Table 2**.

Table 2

Group	Maximum quantity of protein in urine at 20 weeks	Percentage of mice with this quantity of protein
A	0	100
B	+++++	97.5
C	+++++	100
D	++	68

0 8 . 3

Using all the information, evaluate the use of stem cells to treat AS in humans.

[4 marks]

The stem cells from wild type mice were effective, as group D had a lower maximum quantity of protein in their urine (++) than groups B and C (+++++).

However, they were not fully effective, as group D still had more protein in their urine than group A (0).

We do not know the results for all the mice in group D, as the table only shows the result for 68% of them. Some D mice may have been cured, or some may have died. We also do not know the actual numerical quantity of protein.

The investigation was only done on mice, not on humans, so the results may not apply to humans. The transplanted stem cells may be rejected

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Turn over ►



by the immune system, and the results were only for 20 weeks, so long-term effects are not known.

0 8 . 4

The scientists carried out further work to investigate how the transplanted stem cells developed after transplantation.

- The scientists transplanted stem cells from wild type male mice into AS female mice.
- After 20 weeks, they found that the quantity of protein in the urine of these female mice had significantly decreased.
- They examined cells from glomeruli in the female mice. Some of these cells contained a Y chromosome.

Suggest how the transplanted stem cells reduce proteinuria.

[2 marks]

The transplanted stem cells (with a Y chromosome) divide and differentiate into specialised glomerular cells, e.g. making normal basement membrane.

This reduces the loss of protein at the glomerulus, preventing protein moving into the filtrate, so less protein is in the urine.



Turn over for the next question

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0 9

A scientist produced transgenic zebrafish.

She obtained a gene from silverside fish. The gene codes for a growth hormone (GH).

She inserted copies of this *GH* gene into plasmids. She then microinjected these recombinant plasmids into fertilised egg cells of zebrafish.

0 9 . 1

Describe how enzymes could be used to insert the *GH* gene into a plasmid.

[2 marks]

A restriction endonuclease is used to cut the plasmid (at a specific recognition site), producing sticky ends complementary to those on the GH gene.

DNA ligase then joins the sticky ends of the GH gene and the plasmid, forming phosphodiester bonds.

0 9 . 2

Microinjection of DNA into fertilised egg cells is a frequent method of producing transgenic fish. However, the insertion of the transferred gene into nuclear DNA may be delayed. Consequently, the offspring of transgenic fish may not possess the desired characteristic.

Suggest and explain how delayed insertion of the *GH* gene could produce offspring of transgenic fish without the desired characteristic.

[2 marks]

Cell division (mitosis) may have already occurred before the GH gene was inserted into the nuclear DNA, so not all the cells of the fish contain the gene.

So the cells that produce gametes may not receive the GH gene, so the offspring do not inherit it.



The scientist investigated whether the transferred *GH* gene increased the growth of transgenic zebrafish. She microinjected 2000 fertilised egg cells with the *GH* plasmid and left 2000 fertilised egg cells untreated. After 12 months, she determined the mean mass of the transgenic and non-transgenic fish.

The results the scientist obtained are shown in **Table 3**.

Table 3

A value of $\pm 2 \times \text{SD}$ from the mean includes over 95% of the data.

Type of zebrafish	Mean mass of zebrafish / g ($\pm 2 \times \text{SD}$)
Transgenic	1.79 (± 0.37)
Non-transgenic	0.68 (± 0.13)

0 9 . 3

Using **Table 3**, what can you conclude about the effectiveness of the *GH* gene on the growth of zebrafish?

[2 marks]

The $\pm 2 \times \text{SD}$ ranges do not overlap (transgenic 1.42 to 2.16 g,

non-transgenic 0.55 to 0.81 g).

*So the *GH* gene causes a significant increase in mass (growth), and the*

difference is not due to chance.

0 9 . 4

Explain how **two** features of the design of this investigation helped to ensure the validity of any conclusions obtained.

Do **not** include calculating the mean or SD in your answer.

[2 marks]

1 *A large sample size (2000 eggs in each group), so the results are representative.*

2 *A control of 2000 untreated eggs for comparison, and 12 months allows time to assess growth.*



1 0

Read the following passage.

North American black bears can hibernate for up to 7 months without food or water. The bears survive using the fat stores in their bodies. The bears build up the fat stores during the summer. During hibernation, the heart rate of black bears decreases from a summer mean of 55 beats per minute to 14 beats per minute. Their metabolic rate falls by 75%.

5

In many mammals, 'uncoupling proteins' help to maintain a constant body temperature during hibernation. Uncoupling proteins are found in the inner mitochondrial membrane and act as proton channels during chemiosmosis. However, these proton channels do not generate ATP.

In the mountains of North America, when winter changes into spring, the coat colour of snowshoe hares changes from white to brown. Climatic changes have caused the snow to melt earlier. This has reduced the survival rate of snowshoe hares in these habitats. The change in coat colour occurs when new fur replaces old fur. This is called moulting. Recent research has shown that snowshoe hares within a population moult at different times. Moulting at different times could be a major factor in ensuring the survival of snowshoe hare populations.

10

15

Use the information in the passage and your own knowledge to answer the following questions.

1 0

1

Black bears can hibernate for up to 7 months without food or water (lines 1–2).

Suggest and explain how.

[3 marks]

The bears use their fat stores in respiration, and the low metabolic rate

(and lack of movement) means less energy is needed, so the fat lasts.

Thick fat also insulates the body, reducing heat loss, and glycerol from fat can be used in gluconeogenesis.

Water is produced by the respiration of fat, and the bears have long

loops of Henle, so they lose very little water, with reduced urination and less evaporation.



1 0 . 2

During hibernation, the heart rate and the metabolic rate of black bears decrease (lines 3–5).

Use your knowledge of the nervous control of heart rate to describe how these are linked.

[4 marks]

The lower metabolic rate means less respiration, so there is less CO_2 in the blood (the blood pH rises).

This is detected by chemoreceptors in the aorta and carotid arteries (and the medulla).

So fewer impulses are sent from the chemoreceptors to the cardiac centre in the medulla oblongata.

The cardiac centre then sends more impulses along the parasympathetic (vagus) nerve and fewer along the sympathetic nerve to the SAN, so the heart rate decreases.

1 0 . 3

In many mammals, 'uncoupling proteins' help to maintain a constant body temperature during hibernation (lines 6–7).

Suggest and explain how.

[2 marks]

The uncoupling proteins allow the passage of protons (H^+) through the inner mitochondrial membrane without going through ATP synthase.

So the energy from the proton gradient is released as heat instead of being used to make ATP, keeping the body warm.

Question 10 continues on the next page

Turn over ►



1 0 . 4

Climatic change has reduced the survival rate of snowshoe hares in mountain habitats (lines 11–13).

Suggest and explain how.

[2 marks]

The snow melts earlier, so hares that are still white are no longer camouflaged against the brown background.

So more hares are seen and killed by predators.

1 0 . 5

Snowshoe hares within a population moult at different times (line 15).

Explain how this could ensure the survival of snowshoe hare populations in these mountain habitats.

[4 marks]

There is variation in moulting time in the population. When the snow melts earlier, hares that moult earlier are camouflaged, so they are less likely to be eaten by predators and more likely to survive.

So the hares that moult earlier are more likely to reproduce.

They pass on the advantageous allele for early moulting to their offspring.

So the frequency of the early-moulting allele increases in future generations (directional selection), so the population survives.

15

END OF QUESTIONS



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